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<p>(51) International Patent Classification <sup>6</sup> : <b>B01J</b></p>	<p><b>A2</b></p>	<p>(11) International Publication Number: <b>WO 98/22208</b>  (43) International Publication Date: 28 May 1998 (28.05.98)</p>
<p>(21) International Application Number: PCT/US97/20219 (22) International Filing Date: 3 November 1997 (03.11.97) (30) Priority Data: 08/745,949 8 November 1996 (08.11.96) US (71) Applicant: AUTOMOTIVE SYSTEMS LABORATORY, INC. [US/US]; Suite B-12, 27200 Haggerty Road, Farmington Hills, MI 48331 (US). (72) Inventors: BURNS, Sean, P.; 2779 Davison Avenue, Auburn Hills, MI 48326 (US). KHANDHADIA, Paresh, S.; 6697 Redford Circle, Troy, MI 48098 (US). (74) Agent: LYON, Lyman, R.; Lyon, P.C., Suite 207, 3883 Telegraph Road, Bloomfield Hills, MI 48302-1476 (US).</p>		<p>(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> <i>Without international search report and to be republished upon receipt of that report.</i></p>
<p>(54) Title: NONAZIDE GAS GENERANT COMPOSITIONS</p> <p>(57) Abstract</p> <p>High nitrogen nonazide gas compositions, useful in inflating passenger restraint gas inflator bags, comprise an amine salt of triazole or tetrazole fuel, and phase stabilized ammonium nitrate (PSAN) as an oxidizer. The combination of the amine azole salt and phase stabilized ammonium nitrate results in gas generants that are relatively more stable and less explosive, have improved ignitability and burn rates, and generate more gas and less solids than known gas generant compositions.</p>		

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## NONAZIDE GAS GENERANT COMPOSITIONS

BACKGROUND OF THE INVENTION

The present invention relates to nontoxic gas generating compositions which upon combustion, rapidly generate gases that are useful for inflating occupant safety restraints in motor vehicles and specifically, the invention relates to nonazide gas generants that produce combustion products having not only acceptable toxicity levels, but that also exhibit a relatively high gas volume to solid particulate ratio at acceptable flame temperatures.

The evolution from azide-based gas generants to nonazide gas generants is well-documented in the prior art. The advantages of nonazide gas generant compositions in comparison with azide gas generants have been extensively described in the patent literature, for example, U.S. Patents No. 4,370,181; 4,909,549; 4,948,439; 5,084,118; 5,139,588 and 5,035,757, the discussions of which are hereby incorporated by reference.

In addition to a fuel constituent, pyrotechnic nonazide gas generants contain ingredients such as oxidizers to provide the required oxygen for rapid combustion and reduce the quantity of toxic gases generated, a catalyst to promote the conversion of toxic oxides of carbon and nitrogen to innocuous gases, and a slag forming constituent to cause the solid and liquid products formed during and immediately after combustion to agglomerate into filterable clinker-like particulates. Other optional additives, such as burning rate enhancers or ballistic modifiers and ignition aids, are used to control the ignitability and combustion properties of the gas generant.

One of the disadvantages of known nonazide gas generant compositions is the amount and physical nature of the solid residues formed during combustion. The solids produced as a result of combustion must be filtered and otherwise kept away from contact with the occupants of the vehicle. It is therefore highly desirable to develop compositions that produce a minimum of solid particulates while still providing adequate quantities of a nontoxic gas to inflate the safety device at a high rate.

It is known that the use of ammonium nitrate as an oxidizer contributes to the gas production with a minimum of solids. To be useful, however, gas generants for automotive applications must be thermally stable when aged for 400 hours or more at 107°C. The compositions must also retain structural integrity when cycled between -40°C and 107°C.

Generally, gas generant compositions using ammonium nitrate are thermally unstable propellants that produce unacceptably high levels of toxic gases, CO and NO<sub>x</sub> for example, depending on the composition of the associated additives such as plasticizers and binders. Known ammonium nitrate compositions are also hampered by poor ignitability, delayed burn rates, and significant performance variability. Several prior art compositions incorporating ammonium nitrate utilize well known ignition aids such as BKNO<sub>3</sub> to solve this problem. However, the addition of an ignition aid such as BKNO<sub>3</sub> is undesirable because it is a highly sensitive and energetic compound.

Yet another problem that must be addressed is that the

U.S. Department of Transportation (DOT) regulations require "cap testing" for gas generants. Because of the sensitivity to detonation of fuels often used in conjunction with ammonium nitrate, most propellants incorporating ammonium nitrate do not pass the cap test unless shaped into large disks, which in turn reduces design flexibility of the inflator.

Accordingly, many nonazide propellants based on ammonium nitrate cannot meet requirements for automotive applications.

Two notable exceptions are disclosed in U.S. Patent No. 5,531,941 in which the use of phase-stabilized ammonium nitrate, triaminoguanidine nitrate, and oxamide is taught, and, in U.S. Patent No. 5,545,272 in which the use of phase-stabilized ammonium nitrate and nitroguanidine is taught. Despite their usefulness in automotive applications, these compositions are still problematic because triaminoguanidine nitrate and nitroguanidine are explosive fuels that complicate transportation requirements and passing the cap test. Furthermore, because of poor ignitability and a relatively low burn rate, the nitroguanidine composition requires a conventional ignition aid such as  $\text{BKNO}_3$ , which is both sensitive and very energetic.

#### Description of the Prior Art

The gas generant compositions described in Poole et al, U.S. Patents No. 4,909,549 and 4,948,439, use tetrazole or triazole compounds in combination with metal oxides and oxidizer compounds (alkali metal, alkaline earth metal, and pure ammonium nitrates or perchlorates) resulting in a relatively unstable generant that decomposes at low

temperatures. Significant toxic emissions and particulate are formed upon combustion. Both patents teach the use of  $\text{BKNO}_3$  as an ignition aid.

The gas generant compositions described in Poole, U.S. Patent No. 5,035,757, result in more easily filterable solid products but the gas yield is unsatisfactory.

Chang et al, U.S. Patent No. 3,954,528, describes the use of triaminoguanidine nitrate ("TAGN") and a synthetic polymeric binder in combination with an oxidizing material. The oxidizing materials include ammonium nitrate ("AN") although the use of phase stabilized ammonium nitrate ("PSAN") is not suggested. The patent teaches the preparation of propellants for use in guns or other devices where large amounts of carbon monoxide and hydrogen are acceptable and desirable.

Grubaugh, U.S. Patent No. 3,044,123, describes a method of preparing solid propellant pellets containing AN as the major component. The method requires use of an oxidizable organic binder (such as cellulose acetate, PVC, PVA, acrylonitrile and styrene-acrylonitrile), followed by compression molding the mixture to produce pellets and by heat treating the pellets. These pellets would certainly be damaged by temperature cycling because commercial AN is used and the composition claimed would produce large amounts of carbon monoxide.

Becuwe, U.S. Patent No. 5,034,072, is based on the use of 5-oxo-3-nitro-1,2,4-triazole as a replacement for other explosive materials (HMX, RDX, TATB, etc.) in propellants and gun powders. This compound is also called 3-nitro-1,2,4-triazole-5-one ("NTO"). The claims appear to cover a gun

powder composition which includes NTO, AN and an inert binder, where the composition is less hygroscopic than a propellant containing ammonium nitrate. Although called inert, the binder would enter into the combustion reaction and produce carbon  
5 monoxide making it unsuitable for air bag inflation.

Lund et al, U.S. Patent No. 5,197,758, describes gas generating compositions comprising a nonazide fuel which is a transition metal complex of an aminoarazole, and in particular are copper and zinc complexes of 5-aminotetrazole and 3-amino-  
10 1,2,4-triazole which are useful for inflating air bags in automotive restraint systems, but generate excess solids.

Wardle et al, U.S. Patent No. 4,931,112, describes an automotive air bag gas generant formulation consisting essentially of NTO (5-nitro-1,2,4-triazole-3-one) and an  
15 oxidizer wherein said formulation is anhydrous.

Ramnarace, U.S. Patent No. 4,111,728, describes gas generators for inflating life rafts and similar devices or that are useful as rocket propellants comprising ammonium nitrate, a polyester type binder and a fuel selected from oxamide and  
20 guanidine nitrate.

Boyars, U.S. Patent No. 4,124,368, describes a method for preventing detonation of ammonium nitrate by using potassium nitrate.

Mishra, U.S. Patent No. 4,552,736, and Mehrotra et al,  
25 U.S. Patent No. 5,098,683, describe the use of potassium fluoride to eliminate expansion and contraction of ammonium nitrate in transition phase.

Chi, U.S. Patent No. 5,074,938, describes the use of phase

stabilized ammonium nitrate as an oxidizer in propellants containing boron and useful in rocket motors.

Canterberry et al, U.S. Patent No. 4,925,503, describes an explosive composition comprising a high energy material, e.g., ammonium nitrate and a polyurethane polyacetal elastomer binder, the latter component being the focus of the invention.

Hass, U.S. Patent No. 3,071,617, describes long known considerations as to oxygen balance and exhaust gases.

Stinecipher et al, U.S. Patent No. 4,300,962, describes explosives comprising ammonium nitrate and an ammonium salt of a nitroazole.

Prior, U.S. Patent No. 3,719,604, describes gas generating compositions comprising aminoguanidine salts of azotetrazole or of ditetrazole.

Poole, U.S. Patent No. 5,139,588, describes nonazide gas generants useful in automotive restraint devices comprising a fuel, an oxidizer and additives.

Chang et al, U.S. Patent No. 3,909,322, teaches the use of nitroaminotetrazole salts with pure ammonium nitrate as gun propellants and gas generants for use in gas pressure actuated mechanical devices such as engines, electric generators, motors, turbines, pneumatic tools, and rockets.

Bucerius et al, U.S. Patent No. 5,198,046, teaches the use of diguanidinium-5,5'-azotetrazolate with  $\text{KNO}_3$  as an oxidizer, for use in generating environmentally friendly, non-toxic gases, and providing excellent thermal stability.

Onishi et al, U.S. Patent No. 5,439,251, teaches the use of a tetrazole amine salt as an air bag gas generating agent



comprising a cationic amine and an anionic tetrazolyl group having either an alkyl with carbon number 1-3, chlorine, hydroxyl, carboxyl, methoxy, aceto, nitro, or another tetrazolyl group substituted via diazo or triazo groups at the 5-position of the tetrazole ring. The focus of the invention is on improving the physical properties of tetrazoles with regard to impact and friction sensitivity, and does not teach the combination of a tetrazole amine salt with any other chemical.

Lund et al, U.S. Patent No. 5,501,823, teaches the use of nonazide anhydrous tetrazoles, derivatives, salts, complexes, and mixtures thereof, for use in air bag inflators.

Highsmith et al, U.S. Patent No. 5,516,377, teaches the use of a salt of 5-nitraminotetrazole, a conventional ignition aid such as  $\text{BKNO}_3$ , and pure ammonium nitrate as an oxidizer, but does not teach the use of phase stabilized ammonium nitrate.

#### SUMMARY OF THE INVENTION

The aforementioned problems are solved by providing a nonazide gas generant for a vehicle passenger restraint system employing ammonium nitrate as an oxidizer and potassium nitrate as an ammonium nitrate phase stabilizer. The fuel, in combination with phase stabilized ammonium nitrate, is selected from the group consisting of amine salts of tetrazoles and triazoles having a cationic amine component and an anionic component. The anionic component comprises a tetrazole or triazole ring, and an R group substituted on the 5-position of the tetrazole ring, or two R groups substituted on the 3- and

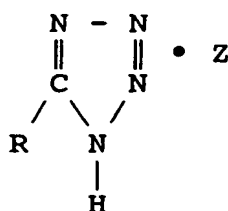
5-positions of the triazole ring. The R group(s) is selected from hydrogen and any nitrogen-containing compounds such as amino, nitro, nitramino, tetrazólyl and triazolyl groups. The cationic amine component is selected from an amine group including ammonia, hydrazine, guanidine compounds such as guanidine, aminoguanidine, diaminoguanidine, triaminoguanidine, dicyandiamide, nitroguanidine, nitrogen subsituted carbonyl compounds such as urea, carbohydrazide, oxamide, oxamic hydrazide, bis-(carbonamide) amine, azodicarbonamide, and hydrazodicarbonamide, and amino azoles such as 3-amino-1,2,4-triazole, 3-amino-5-nitro-1,2,4-triazole, 5-aminotetrazole and 5-nitraminotetrazole. Optional inert additives such as clay or silica may be used as a binder, slag former, coolant or processing aid. Optional ignition aids comprised of nonazide propellants may also be utilized in place of conventional ignition aids such as BKNO<sub>3</sub>.

The gas generants of this invention are prepared by dry blending and compaction of the comminuted ingredients.

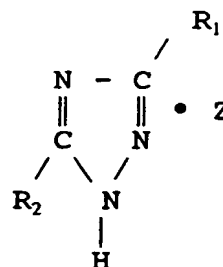
#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with the present invention, the preferred high nitrogen nonazides employed as primary fuels in gas generant compositions include, in particular, amine salts of tetrazole and triazole selected from the group including monoguanidinium salt of 5,5'-Bis-1H-tetrazole (BHT·1GAD), diguanidinium salt of 5,5'-Bis-1H-tetrazole (BHT·2GAD), monoaminoguanidinium salt of 5,5'-Bis-1H-tetrazole (BHT·1AGAD), diaminoguanidinium salt of 5,5'-Bis-1H-tetrazole (BHT·2AGAD), monohydrazinium salt of 5,5'-Bis-1H-tetrazole (BHT·1HH),

dihydrazinium salt of 5,5'-Bis-1H-tetrazole (BHT·2HH),  
 monoammonium salt of 5,5'-bis-1H-tetrazole (BHT·1NH<sub>3</sub>),  
 diammonium salt of 5,5'-bis-1H-tetrazole (BHT·2NH<sub>3</sub>), mono-3-  
 amino-1,2,4-triazolium salt of 5,5'-bis-1H-tetrazole  
 5 (BHT·1ATAZ), di-3-amino-1,2,4-triazolium salt of 5,5'-bis-1H-  
 tetrazole (BHT·2ATAZ), diguanidinium salt of 5,5'-Azobis-1H-  
 tetrazole (ABHT·2GAD), and monoammonium salt of 5-Nitramino-1H-  
 tetrazole (NAT·1NH<sub>3</sub>). The nonazide fuel generally comprises  
 15-65%, and preferably comprises 20-55%, by weight of the total  
 10 gas generant composition.



Formula I



Formula II

A generic amine salt of tetrazole as shown in Formula I  
 includes a cationic amine component, Z, and an anionic  
 component comprising a tetrazole ring and an R group  
 substituted on the 5-position of the tetrazole ring. A generic  
 25 amine salt of triazole as shown in Formula II includes a  
 cationic amine component, Z, and an anionic component  
 comprising a triazole ring and two R groups substituted on the  
 3- and 5- positions of the triazole ring, wherein R<sub>1</sub> may or may  
 not be structurally synonymous with R<sub>2</sub>. An R component is  
 30 selected from a group including hydrogen or any nitrogen-  
 containing compound such as an amino, nitro, nitramino, or a

tetrazolyl or triazolyl group from Formula I or II, respectively, substituted directly or via amine, diazo, or triazo groups. The compound Z is an amine that forms a cation by displacing a hydrogen atom at the 1-position of either  
5 formula, and is selected from an amine group including ammonia, hydrazine, guanidine compounds such as guanidine, aminoguanidine, diaminoguanidine, triaminoguanidine, dicyandiamide and nitroguanidine, nitrogen substituted carbonyl compounds such as urea, carbohydrazide, oxamide, oxamic  
10 hydrazide, bis-(carbonamide) amine, azodicarbonamide, and hydrazodicarbonamide, and amino azoles such as 3-amino-1,2,4-triazole, 3-amino-5-nitro-1,2,4-triazole, 5-aminotetrazole, 3-nitramino-1,2,4-triazole, 5-nitraminotetrazole, and melamine.

The foregoing amine salts of tetrazole or triazole are  
15 dry-mixed with phase stabilized ammonium nitrate. The oxidizer is generally employed in a concentration of about 35 to 85% by weight of the total gas generant composition. The ammonium nitrate is stabilized by potassium nitrate, as described in Example 16, and as taught in co-owned U.S. Patent No.  
20 5,531,941, entitled, "Process For Preparing Azide-Free Gas Generant Composition", and granted on July 2, 1996, incorporated herein by reference. The PSAN comprises 85-90% AN and 10-15% KN and is formed by any suitable means such as co-crystallization of AN and KN, so that the solid-solid phase  
25 changes occurring in pure ammonium nitrate (AN) between -40°C and 107°C are prevented. Although KN is preferably used to stabilize pure AN, one skilled in the art will readily appreciate that other stabilizing agents may be used in

conjunction with AN.

If a slag former, binder, processing aid, or coolant is desired, inert components such as clay, diatomaceous earth, alumina, or silica are provided in a concentration of .1-10% of the gas generant composition, wherein toxic effluents generated upon combustion are minimized.

Optional ignition aids, used in conjunction with the present invention, are selected from nonazide gas generant compositions comprising a fuel selected from a group including triazole, tetrazolone, aminotetrazole, tetrazole, or bitetrazole, or others as described in U.S. Patent No. 5,139,588 to Poole, the teachings of which are herein incorporated by reference. Conventional ignition aids such as BKNO<sub>3</sub> are no longer required because the tetrazole or triazole based fuel, when combined with phase stabilized ammonium nitrate, significantly improves ignitability of the propellant and also provides a sustained burn rate.

The manner and order in which the components of the fuel composition of the present invention are combined and compounded is not critical so long as a uniform mixture is obtained and the compounding is carried out under conditions which do not cause decomposition of the components employed. For example, the materials may be wet blended, or dry blended and attrited in a ball mill or Red Devil type paint shaker and then pelletized by compression molding. The materials may also be ground separately or together in a fluid energy mill, sweco vibroenergy mill or bantam micropulverizer and then blended or further blended in a v-blender prior to compaction.

The present invention is illustrated by the following examples, wherein the components are quantified in weight percent of the total composition unless otherwise stated.

Values for examples 1-3 and 16-20 were obtained experimentally.

5 Examples 18-20 provide equivalent chemical percentages as found in Examples 1-3 and are included for comparative purposes and to elaborate on the laboratory findings. Values for examples 4-15 are obtained based on the indicated compositions. The primary gaseous products are  $N_2$ ,  $H_2O$ , and  $CO_2$ , and, the elements  
10 which form solids are generally present in their most common oxidation state. The oxygen balance is the weight percent of  $O_2$  in the composition which is needed or liberated to form the stoichiometrically balanced products. Therefore, a negative oxygen balance represents an oxygen deficient composition  
15 whereas a positive oxygen balance represents an oxygen rich composition.

When formulating a composition, the ratio of PSAN to fuel is adjusted such that the oxygen balance is between -4.0% and +1.0%  $O_2$  by weight of composition as described above. More  
20 preferably, the ratio of PSAN to fuel is adjusted such that the composition oxygen balance is between -2.0% and 0.0%  $O_2$  by weight of composition. It can be appreciated that the relative amount of PSAN and fuel will depend both on the additive used to form PSAN as well as the nature of the selected fuel.

25 In Tables 1 and 2 below, PSAN is phase-stabilized with 15% KN of the total oxidizer component in all cases except those marked by an asterisk. In that case, PSAN is phase-stabilized with 10% KN of the total oxidizer component.

In accordance with the present invention, these formulations will be both thermally and volumetrically stable over a temperature range of  $-40^{\circ}\text{C}$  to  $107^{\circ}\text{C}$ , produce large volumes of non-toxic gases, produce minimal solid particulates, ignite readily and burn in a repeatable manner, contain no toxic, sensitive, or explosive starting materials, be non-toxic, insensitive, and non-explosive in final form, and have a burn rate at 1000 psi of greater than 0.40 inches per second.

Table 1

EX	Composition by Weight Percent	Moles of Gas/ 100g of Generant	Grams of Solids/ 100g of Generant	Oxygen Balance by Weight Percent	Burn Rate at 1000 psi (in/sec)
1	76.43% PSAN 23.57% BHT•2NH <sub>3</sub>	4.00	5.34	0.0%	0.48
2	75.40% PSAN 24.60% BHT•2NH <sub>3</sub>	4.00	5.27	-1.0%	0.47
3	72.32% PSAN 27.68% BHT•2NH <sub>3</sub>	4.00	5.05	-4.0%	0.54

Table 2

EX	Composition in Weight Percent	Mol Gas/ 100g of Generant	Grams of Solids/ 100g of Generant	Oxygen Balance in Weight Percent
4	73.06% PSAN* 26.94% BHT•2NH <sub>3</sub>	4.10	3.40	-4.0%
5	76.17% PSAN* 23.83% BHT•2NH <sub>3</sub>	4.10	3.55	-1.0%
6	78.25% PSAN* 21.75% BHT•2NH <sub>3</sub>	4.10	3.65	+1.0%
7	73.08% PSAN 26.92% BHT•1GAD	3.95	5.11	-4.0%
8	76.08% PSAN 23.92% BHT•1GAD	3.95	5.32	-1.0%
9	78.08% PSAN 21.92% BHT•1GAD	3.95	5.46	+1.0%
10	73.53% PSAN 26.47% ABHT•2GAD	3.95	5.14	-4.0%
11	76.48% PSAN 23.52% ABHT•2GAD	3.95	5.34	-1.0%
12	78.45% PSAN 21.55% ABHT•2GAD	3.95	5.48	+1.0%
13	46.27% PSAN 53.73% NAT•1NH <sub>3</sub>	3.94	3.23	-4.0%
14	52.26% PSAN 47.74% NAT•1NH <sub>3</sub>	3.94	3.65	-1.0%
15	56.25% PSAN 43.75% NAT•1NH <sub>3</sub>	3.95	3.93	+1.0%



## Example 16 - Illustrative

Phase-stabilized ammonium nitrate (PSAN) consisting of 85 wt% ammonium nitrate (AN) and 15 wt% potassium nitrate (KN) was prepared as follows. 2125g of dried AN and 375g of dried KN were added to a heated jacket double planetary mixer. Distilled water was added while mixing until all of the AN and KN had dissolved and the solution temperature was 66-70°C. Mixing was continued at atmospheric pressure until a dry, white powder formed. The product was PSAN. The PSAN was removed from the mixer, spread into a thin layer, and dried at 80°C to remove any residual moisture.

## Example 17 - Illustrative

The PSAN prepared in example 16 was tested as compared to pure AN to determine if undesirable phase changes normally occurring in pure AN had been eliminated. Both were tested in a DSC from 0°C to 200°C. Pure AN showed endotherms at about 57°C and about 133°C, corresponding to solid-solid phase changes as well as a melting point endotherm at about 170°C. PSAN showed an endotherm at about 118°C corresponding to a solid-solid phase transition and an endotherm at about 160°C corresponding to the melting of PSAN.

Pure AN and the PSAN prepared in example 16 were compacted into 12mm diameter by 12mm thick slugs and measured for volume expansion by dilatometry over the temperature range -40°C to 140°C. When heating from -40°C to 140°C the pure AN experienced a volume contraction beginning at about -34°C, a volume expansion beginning at about 44°C, and a volume

contraction beginning at about 90°C and a volume expansion beginning at about 130°C. The PSAN did not experience any volume change when heated from -40°C to 107°C. It did experience a volume expansion beginning at about 118°C.

5           Pure AN and the PSAN prepared in example 16 were compacted into 32mm diameter by 10mm thick slugs, placed in a moisture-sealed bag with desiccant, and temperature cycled between -40°C and 107°C. 1 cycle consisted of holding the sample at 107°C for 1 hour, transitioning from 107°C to -40°C at a constant  
10 rate in about 2 hours, holding at -40°C for 1 hour, and transitioning from -40°C to 107°C at a constant rate in about 1 hour. After 62 complete cycles, the samples were removed and observed. The pure AN slug had essentially crumbled to powder while the PSAN slug remained completely intact with no cracking  
15 or imperfections.

The above example demonstrates that the addition of KN up to and including 15 wt% of the co-precipitated mixtures of AN and KN effectively removes the solid-solid phase transitions present in AN over the automotive application range of -40°C to  
20 107°C.

#### Example 18

A mixture of PSAN and  $\text{BHT} \cdot 2\text{NH}_3$  was prepared having the following composition in percent by weight: 76.43% PSAN and 23.57%  $\text{BHT} \cdot 2\text{NH}_3$ . The weighed and dried components were blended  
25 and ground to a fine powder by tumbling with ceramic cylinders in a ball mill jar. The powder was separated from the grinding cylinders and granulated to improve the flow characteristics of

the material. The granules were compression molded into pellets on a high speed rotary press. Pellets formed by this method were of exceptional quality and strength.

5 The burn rate of the composition was 0.48 inches per second at 1000 psi. The burn rate was determined by measuring the time required to burn a cylindrical pellet of known length at a constant pressure. The pellets were compression molded in a 1/2" diameter die under a 10 ton load, and then coated on the sides with an epoxy/titanium dioxide inhibitor which prevented  
10 burning along the sides.

The pellets formed on the rotary press were loaded into a gas generator assembly and found to ignite readily and inflate an airbag satisfactorily, with minimal solids, airborne particulates, and toxic gases produced. Approximately 95% by  
15 weight of the gas generant was converted to gas. The ignition aid used contained no booster such as  $\text{BKNO}_3$ , but only high gas yield nonazide pellets such as those described in U.S. Patent No. 5,139,588.

As tested with a standard Bureau of Mines Impact  
20 Apparatus, the impact sensitivity of this mixture was greater than 300  $\text{kp}\cdot\text{cm}$ . As tested according to U.S. D.O.T. procedures pellets of diameter 0.184" and thickness of 0.080" did not deflagrate or detonate when initiated with a No. 8 blasting cap.

#### 25 Example 19

A mixture of PSAN and  $\text{BHT}\cdot 2\text{NH}_3$  was prepared having the following composition in percent by weight: 75.40% PSAN and

24.60% BHT•2NH<sub>3</sub>. The composition was prepared as in Example 18, and again formed pellets of exceptional quality and strength. The burn rate of the composition was 0.47 inches per second at 1000 psi.

5       The pellets formed on the rotary press were loaded into a gas generator assembly. The pellets were found to ignite readily and inflate an airbag satisfactorily, with minimal solids, airborne particulates, and toxic gases produced. Approximately 95% by weight of the gas generant was converted  
10 to gas.

As tested with a standard Bureau of Mines Impact Apparatus, the impact sensitivity of this mixture was greater than 300 kp•cm. As tested according to U.S. Department of Transportation procedures, pellets of diameter 0.250" and  
15 thickness of 0.125" did not deflagrate or detonate when initiated with a No. 8 blasting cap.

#### Example 20

A mixture of PSAN and BHT•2NH<sub>3</sub> was prepared having the following composition in percent by weight: 72.32% PSAN and  
20 27.68% BHT•2NH<sub>3</sub>. The composition was prepared as in example 18, except that the weight ratio of grinding media to powder was tripled. The burn rate of this composition was found to be 0.54 inches per second at 1000 psi. As tested with a standard Bureau of Mines Impact Apparatus, the impact sensitivity of  
25 this mixture was greater than 300 kp•cm. This example demonstrates that the burn rate of the compositions of the present invention can be increased with more aggressive

grinding. As tested according to U.S.D.O.T. regulations, pellets having a diameter of .184" and thickness of 0.090" did not deflagrate or detonate when initiated with a No. 8 blasting cap.

5 In accordance with the present invention, the ammonium nitrate-based propellants are phase stabilized, sustain combustion at pressures above ambient, and provide abundant nontoxic gases while minimizing particulate formation. Because the amine salts of tetrazole and triazole, in combination with  
10 PSAN, are easily ignitable, conventional ignition aids such as BKNO<sub>3</sub> are not required to initiate combustion.

Furthermore, due to reduced sensitivity and in accordance with U.S.D.O.T. regulations, the compositions readily pass the cap test at propellant tablet sizes optimally designed for use  
15 within the air bag inflator. As such, a significant advantage of the present invention is that it contains nonhazardous and nonexplosive starting materials, all of which can be shipped with minimal restrictions.

Comparative data of the prior art and that of the present  
20 invention are shown in Table 3 to illustrate the gas generating benefit of utilizing the tetrazole and triazole amine salts in conjunction with PSAN.

Table 3 - Comparative Gas Production

U.S. Patent No.	mol gas/ 100 g prop.	mol gas/ 100 cm <sup>3</sup> gas generant	cm <sup>3</sup> gas generant/ mol gas	Comparative Propellant Volume For Equal Amount of Gas Output
4,931,111 Azide	1.46	3.43	29.17	193%
5,139,588 Nonazide	2.18	4.96	20.16	133%
5,431,103 Nonazide	1.58	5.26	19.03	126%
Present Invention	4.00	6.60	15.15	100%

As shown in Table 3, and in accordance with the present invention, PSAN and amine salts of tetrazole or triazole produce a significantly greater amount of gas per cubic centimeter of gas generant volume as compared to prior art compositions. This enables the use of a smaller inflator due to a smaller volume of gas generant required. Due to greater gas production, formation of solids are minimized thereby allowing for smaller and simpler filtration means which also contributes to the use of a smaller inflator.

While the foregoing examples illustrate the use of preferred fuels and oxidizers it is to be understood that the practice of the present invention is not limited to the particular fuels and oxidizers illustrated and similarly does not exclude the inclusion of other additives as described above and as defined by the following claims.

## WE CLAIM:

1. A gas generant composition useful for inflating an automotive air bag passive restraint system comprising a mixture of:

a high-nitrogen nonazide fuel selected from the class consisting of 1-, 3-, and 5-substituted amine salts of triazoles, and, 1- and 5-substituted amine salts of tetrazoles; and

an oxidizer selected from the group consisting of phase stabilized ammonium nitrate.

2. A gas generant composition as claimed in Claim 1 wherein said fuel is employed in a concentration of 15 to 65% by weight of the gas generant composition, and, said oxidizer is employed in a concentration of 35 to 85% by weight of the gas generant composition.

3. A gas generant composition as claimed in Claim 2 further comprising an inert combination slag former, binder, processing aid, and coolant selected from the group comprising clay, diatomaceous earth, alumina, and silica wherein said slag former is employed in a concentration of .1 to 10% by weight of the gas generant composition.

4. A gas generant composition as claimed in Claim 1 further comprising an ammonium nitrate stabilizing agent selected from the group comprising potassium nitrate wherein said stabilizing agent is employed in a concentration of 10-15% by weight of the total phase stabilized ammonium nitrate.

5. A gas generant composition as claimed in Claim 2 comprising a mixture of monoguanidinium salt of 5,5'-Bis-1H-

tetrazole and phase stabilized ammonium nitrate.

6. A gas generant composition as claimed in Claim 2 comprising a mixture of diguanidinium salt of 5,5'-Bis-1H-tetrazole and phase stabilized ammonium nitrate.

7. A gas generant composition as claimed in Claim 2 comprising a mixture of monoaminoguanidinium salt of 5,5'-Bis-1H-tetrazole and phase stabilized ammonium nitrate.

8. A gas generant composition as claimed in Claim 2 comprising a mixture of diaminoguanidinium salt of 5,5'-Bis-1H-tetrazole and phase stabilized ammonium nitrate.

9. A gas generant composition as claimed in Claim 2 comprising a mixture of monoammonium salt of 5-Nitramino-1H-tetrazole and phase stabilized ammonium nitrate.

10. A gas generant composition as claimed in Claim 2 comprising a mixture of monohydrazinium salt of 5,5'-Bis-1H-tetrazole and phase stabilized ammonium nitrate.

11. A gas generant composition as claimed in Claim 2 comprising a mixture of dihydrazinium salt of 5,5'-Bis-1H-tetrazole and phase stabilized ammonium nitrate.

12. A gas generant composition as claimed in Claim 2 comprising a mixture of monoammonium salt of 5,5'-bis-1H-tetrazole and phase stabilized ammonium nitrate.

13. A gas generant composition as claimed in Claim 2 comprising a mixture of diammonium salt of 5,5'-bis-1H-tetrazole and phase stabilized ammonium nitrate.

14. A gas generant composition as claimed in Claim 2 comprising a mixture of mono-3-amino-1,2,4-triazolium salt of 5,5'-bis-1H-tetrazole and phase stabilized ammonium nitrate.



15. A gas generant composition as claimed in Claim 2 comprising a mixture of di-3-amino-1,2,4-triazolium salt of 5,5'-bis-1H-tetrazole and phase stabilized ammonium nitrate.

16. A gas generant composition as claimed in Claim 2 comprising a mixture of diguanidinium salt of 5,5'-Azobis-1H-tetrazole and phase stabilized ammonium nitrate.